Inflation Dynamics in Europe: The Role of Employment Adjustment Costs

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Abstract: This paper tests whether accounting for labor market frictions improves the empirical fit of the forward-looking New Keynesian Phillips Curve in Europe. This model of staggered price setting implies that inflation dynamics are driven by the present-value of future real marginal costs. We relax a rigid assumption about factor markets and use a measure of marginal costs that broadens the conventionally used labor share of income by reflecting the costs of adjusting employment. We provide GMM evidence and exploit forecasts generated by VAR models to assess the extent to which the model matches the behavior of actual inflation. The model shows that allowing for costly adjustment of labor input contributes to the explanation of inflation dynamics and leads to parameter estimates that replicate actual inflation remarkably well.

Keywords: employment adjustment costs, New Keynesian Phillips Curve, present-value model, GMM, bootstrap

JEL classification: E31, E32

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1 Introduction

In recent years, sticky-price models with monopolistic competition have become the consensus framework to think about inflation and monetary policy. These models typically give rise to a forward-looking Phillips curve that relates current inflation to expected future inflation and current real marginal costs. Furthermore, solving this model forward implies that inflation equals the present value of future marginal costs. Many empirical contributions aim at testing the explanatory power of this New-Keynesian Phillips Curve (NKPC) - with limited success. In most of these empirical applications, real marginal costs, i.e. the ratio of the real wage to the marginal productivity of labor, are approximated by deviations of the labor share of income from its mean. This approximation follows from a set of assumptions, one of them being the assumption of perfect labor markets with flexible wages, no overhead labor and the absence of costs of adjusting the labor input.

This paper shows that the latter is not an innocuous assumption. Labor market frictions are a crucial determinant of firms' marginal costs and, thus, of inflation. We provide evidence that accounting for labor market frictions in the sense of employment adjustment costs at the firm level greatly improves the empirical fit of the forward-looking Phillips curve for aggregate Euro area data. We augment the labor share of income measure of marginal costs by some measure of labor adjustment costs following Rotemberg and Woodford (1999). GMM estimates support the significance of this additional explanatory variable. Moreover, we use the seminal method of Campbell and Shiller (1987) to study the forward-looking nature of inflation dynamics, exploit the present-value implications of the model, and show that accounting for labor adjustment costs generates a series of model-consistent or fundamental inflation that closely tracks the dynamics of actual inflation. Standard measures of fit show that the augmented model replicates observed inflation rates far better than the conventional empirical model.[2]

The present paper is organized as follows. Section 2 briefly sketches a log-linear version of the New-Keynesian model of inflation dynamics and presents a measure of employment adjustment costs. Section 3 introduces two alternative empirical approaches,

[2]Recently, a number of papers accounts for a richer supply side in modelling the NKPC for EMU data. Gagnon and Khan (2005), among others, introduce a variety of alternative production technologies and Matheron (2005) allows for firm-specific labor and capital.

namely GMM estimation and VAR-based tests of forward-looking present-value models. Section 4 describes the data set and section 5 discusses the main results. Finally, section 6 concludes.

2 Inflation dynamics and marginal costs

In this section we use a stylized log-linear model to derive the basic present-value relation for inflation that is central to most specifications of the New Keynesian Phillips Curve. Consider the case of staggered price setting put forward by Calvo (1983). Each firm adjusts its price during the current period with a fixed probability $1-\mu$ where $0<\mu<1$. Firms minimize the discounted future deviations of their price from the price they would set if prices were fully flexible. It can be shown (see, e.g. Walsh 2003, chap. 5) that this problem results in an optimal reset price

$$p_t^* = (1-\phi\mu)\sum_{k=0}^{\infty}(\phi\mu)^k E_t\{nmc_{t+k}\} \tag{1}$$

with a subjective discount factor ϕ. The optimal reset price is set equal to a weighted average of the prices that it would have expected to set in the future if there were no rigidities. In a frictionless market this price would equal a fixed markup (which we set, without loss of generality, equal to zero) over marginal costs. In setting prices each firm takes the expected path of future nominal marginal costs, nmc_t, into account. The price level p_t is given as a convex combination of the lagged price level and the optimal reset price p_t^*

$$p_t = \mu p_{t-1} + (1-\mu)p_t^* \tag{2}$$

Combining these two equations gives the aggregate price level as the present-value of expected future nominal marginal costs

$$p_t = \mu p_{t-1} + (1-\mu)(1-\phi\mu)\sum_{k=0}^{\infty}(\phi\mu)^k E_t\{nmc_{t+k}\} \tag{3}$$

The higher the probability μ, the more persistent is the price level. In the limiting case of perfectly flexible prices (i.e. $\mu\to 0$), the optimal reset price and, thus, the price level are determined only by the current level of marginal costs, $p_t = nmc_t$. From this model we can derive the NKPC (see, e.g. Galí and Gertler, 1999)

$$\pi_t = \phi E_t\pi_{t+1} + \gamma\hat{\varphi}_t \tag{4}$$

Inflation (in deviation from the zero inflation steady state) is determined by expected future inflation and current real activity proxied by real marginal costs (in deviation from steady state), where $\pi_t = p_t - p_{t-1}$ is the inflation rate, $\hat{\varphi}_t$ denotes a measure of real marginal costs (in deviations from mean) and E_t is the expectations operator. The composite parameter γ is given by $\frac{(1-\mu)(1-\phi\mu)}{\mu}$. Solving the model forward yields

$$\pi_t = \gamma \sum_{k=0}^{\infty} \phi^k E_t \hat{\varphi}_{t+k} \tag{5}$$

Equation (5) states that the inflation rate at time t is a fraction of the present-value of the expected path of future real marginal costs. Conventionally, real marginal costs are measured by deviations of the labor share of income from its mean, $\hat{s}_t$.[3] Let's assume a production technology with fixed capital-input, e.g. $Y_t = A_t L_t$. Nominal marginal costs are then given by the ratio of the nominal wage to the marginal productivity of labor

$$\left(\frac{\partial(W_t L_t)}{\partial L_t}\right)\left(\frac{\partial Y_t}{\partial L_t}\right)^{-1} = \frac{W_t}{A_t} \tag{6}$$

where W_t is the nominal wage and L_t is the labor input. Dividing this expression by the price level P_t yields real marginal costs φ_t as

$$\varphi_t = \frac{W_t}{P_t A_t} = \frac{W_t L_t}{P_t Y_t} = S_t \tag{7}$$

where $S_t = \frac{W_t L_t}{P_t Y_t}$ is the labor share of income. Linearizing this expression gives a simple representation of deviations of marginal costs from its mean in terms of the deviations of the labor share from its steady-state value

$$\hat{\varphi}_t = \hat{s}_t \tag{8}$$

However, using the labor share to measure marginal costs imposes a set of restrictions. Here we extend the model with a richer supply side. The novel feature of this paper is to depart from the assumption of frictionless labor markets and to consider the role of costly labor input adjustment.

It is now widely accepted conventional wisdom that labor markets in EMU are particularly rigid. In particular, non-wage costs such as hiring and firing costs and em-

[3]For empirical evidence of the present-value implications of this model with marginal costs approximated by the labor share see Galí, Gertler, and López-Salido (2001), Kurmann (2003), and Tillmann (2005).

ployment protection regulation contribute to labor market rigidity.[4] Here we capture these frictions in a simple and stylized representation of employment adjustment costs. Rotemberg and Woodford (1999, pp. 1072/73) profoundly survey measures of marginal costs and derive a measure of employment adjustment costs from a model with convex costs of changing the labor input. Their simple representation was subsequently employed by Batini, Jackson, and Nickell (2005) and Sbordone (2005) to estimate inflation dynamics.[5] While Batini, Jackson, and Nickell find a role for labor adjustment costs in explaining UK inflation dynamics, Sbordone obtains insignificant coefficients in a forward-looking Phillips curve fitted to U.S. data.[6]

We assess the role of employment adjustment costs for European inflation dynamics and follow Rotemberg and Woodford (1999) by supplementing an additional term to marginal costs that measures the difference between the growth rate of employment today and the expected growth rate of employment in the next period

$$\hat{\varphi}_t = \hat{s}_t + \delta \left(\Delta l_t - E_t \Delta l_{t+1} \right) \tag{9}$$

where Δl_t is the first difference of (log) employment l_t and δ is a constant parameter that measures the impact of changes in employment growth on real marginal costs and, thus, on inflation.[7] This expression specifies that marginal costs increase if employment is temporarily high, i.e. if $\Delta l_t > E_t \Delta l_{t+1}$. The correction of the labor share in (9) implies a measure of real marginal costs that is more procyclical than the labor share of income. A profound derivation of this log-linearized measure can be found in Rotemberg and Woodford's survey.

Alternatively, we follow Chang, Doh and Schorfheide (2006) and use the squared change in employment as a simple reduced-form measure of quadratic cost to firms. Again, we

[4] See OECD (2004) for stylized facts on the degree of labor market regulation in European countries. Recent theoretical contributions of Bentolila and Bertola (1990) and Saint-Paul and Bentolila (2001) also point to the relevance of hiring and firing costs for European employment dynamics. The microeconomic literature is surveyed by Hamermesh and Pfann (1996).

[5] Sbordone (1996) presents an early model that incorporates costs of adjusting hours.

[6] Galí, Gertler, and López-Salido (2005) also point to labor adjustment costs with respect to EMU data but do not estimate their role for inflation dynamics.

[7] Adjustment costs are assumed to be external in the sense that the additional inputs that must be purchased are something other than additonal labor, so that we can still use the conventional definiton of the labor share, see Bentolila and Saint-Paul (2003).

do not take a particular stand on the microfoundations of the nature of these frictions

$$\hat{\varphi}_t = \hat{s}_t + \delta \left(\Delta l_t\right)^2 \quad (10)$$

Recently, a small number of papers integrates labor market frictions into sticky-price models of the business cycle. Among them, Krause and Lubik (2003), Trigari (2003), and Walsh (2005) include labor market search in otherwise standard New Keynesian models that generates equilibrium unemployment while wage bargaining gives rise to real wage rigidity. Interestingly, Krause and Lubik (2003, p. 3) find that accounting for real wage rigidity barely affects inflation. The main reason, they claim, is that "in models with labor market frictions, real marginal costs are not equal to the real wage." They argue that "the presence of frictions separates real marginal costs and inflation dynamics". They also add an additional term to (8) that depends on the expected cost of posting a new vacancy. However, they do not attempt to estimate the explanatory power of this extension. In this paper, we continue this line of reasoning with the simple representations given by (9) and (10).

3 The empirical approach

In this section we briefly portray two alternative approaches to asses the explanatory power of the augmented forward-looking Phillips curve.

3.1 GMM estimation

The most obvious approach to estimate the NKPC and to take account of forward-looking variables is to replace expected variables with their realizations and employ the GMM estimator. Let $\mathbf{G}_t$ denote a vector of instruments that are observed at time t. Imposing rational expectations defines the following orthogonality condition, that is the reduced form specification of the GMM estimation

$$E_t \left\{ \left(\pi_t - \phi \pi_{t+1} - \gamma_s \hat{s}_t + \gamma_l \left(\Delta l_t - \Delta l_{t+1} \right) \right) \mathbf{G}_t \right\} = 0$$

The vector of instruments includes five lags of inflation, the labor share, changes in employment growth and the output gap as well as two lags of the short-term interest rate. From this orthogonality condition we obtain estimates of the reduced form coefficients, i.e. the discount factor ϕ, the impact of movements in the labor share γ_s, and

the impact of employment adjustment costs γ_l. In a separate specification we replace $\Delta l_t - \Delta l_{t+1}$ by the quadratic cost measure $(\Delta l_t)^2$ presented above.
To obtain an orthogonality condition in a structural form, we plug the definition of the slope coefficient $\gamma = (1-\mu)(1-\mu\phi)\mu^{-1}$ into the Phillips curve and impose rational expectations. Due to the fact that GMM is sensitive to the way this nonlinear orthogonality condition is imposed, we specify two alternative conditions

$$\begin{aligned} (I) \qquad & E_t \left\{ \left(\mu\pi_t - \mu\phi\pi_{t+1} - (1-\mu)(1-\mu\phi)\left(\hat{s}_t + \delta\left(\Delta l_t - \Delta l_{t+1}\right)\right)\right) \mathbf{G}_t \right\} &=& \ 0 \\ (II) \qquad & E_t \left\{ \left(\pi_t - \phi\pi_{t+1} - (1-\mu)(1-\mu\phi)\mu^{-1}\left(\hat{s}_t + \delta\left(\Delta l_t - \Delta l_{t+1}\right)\right)\right) \mathbf{G}_t \right\} &=& \ 0 \end{aligned}$$

From these orthogonality conditions we can obtain estimates of the structural parameters of the model, i.e. the discount factor ϕ, the degree of nominal stickiness μ, and the impact of employment adjustment costs δ.

3.2 VAR projections

Remember that inflation is the present-value of expected real marginal costs. Taking account of costly employment adjustment by combining equation (5) and (9) thus leads to the following present-value relation for the inflation rate

$$\begin{aligned} \pi_t &= \gamma \sum_{k=0}^{\infty} \phi^k E_t \hat{\varphi}_{t+k} \qquad (11) \\ &= \gamma \sum_{k=0}^{\infty} \phi^k E_t \left\{ \hat{s}_{t+k} - \delta E_{t+k} \Delta^2 l_{t+k+1} \right\} \\ &= \gamma_s \sum_{k=0}^{\infty} \phi^k E_t \hat{s}_{t+k} - \gamma_l \sum_{k=0}^{\infty} \phi^k E_t \Delta^2 l_{t+k+1} \end{aligned}$$

where $\Delta l_t - E_t \Delta l_{t+1} = -\Delta^2 l_{t+1}$. The coefficients γ_s and γ_l are reduced-form parameters to be estimated. Hence, we do not restrict the slope coefficient of the labor share and the employment adjustment costs to be identical. Inflation is driven by the present-value of the future labor share as well as entire future changes in the growth rate of employment.
To assess the robustness of the specification with respect to the approximation of adjustment costs, we also include a quadratic measure of adjustment cost

$$\pi_t = \gamma_s \sum_{k=0}^{\infty} \phi^k E_t \hat{s}_{t+k} + \gamma_l \sum_{k=0}^{\infty} \phi^k E_t \left(\Delta l_{t+k}\right)^2 \qquad (12)$$

Previous contributions, e.g. Sbordone (2002 and 2005), Kurmann (2005), and Tillmann (2005), study only the present-value of the labor share as a driving variable of inflation, i.e. they assume $\gamma_l \equiv 0$. Hence, in this paper the inflation rate is, in addition to the annuity value of the labor share, driven by the present-value of employment adjustment costs.

To assess the explanatory power of the Calvo model of staggered price setting with labor market frictions, we construct an implied series for the forward-looking terms and contrast model-consistent inflation rates with actually observed inflation rates. We assume that the information contained in a small atheoretical three-dimensional VAR is a subset of the market's full information set. Campbell and Shiller (1987) propose a well-known framework to assess the fit of forward-looking present-value models. The virtue of this approach is its robustness to omitted information.

Let

$$\mathbf{Z}_t = \left[\hat{s}_t, ..., \hat{s}_{t-q+1}, \pi_t, ..., \pi_{t-q+1}, \Delta^2 l_t, ..., \Delta^2 l_{t-q+1}\right]' \tag{13}$$

be an approximation to agents' information set. Hence, market information can be described by past realizations of the labor share, inflation, and the changes in the growth rates of employment. The vector $\mathbf{Z}_t$ follows a VAR(q) in companion form

$$\mathbf{Z}_{t+1} = \mathbf{A}\mathbf{Z}_t + \mathbf{\Gamma}_{Z_{t+1}} \tag{14}$$

where $\mathbf{\Gamma}_{Z_{t+1}} = [u_{1t,}0, ..., 0, u_{2t}, 0, ..., 0, u'_{3t}, 0..., 0]$ represents innovations to agents' information set and $\mathbf{A}$ is the $3q \times 3q$ companion matrix. We know that forecasts based on the econometrician's information set $\mathcal{I}_t$, which includes only current and lagged values of the variables in $\mathbf{Z}_t$, are given by the multi-period forecasting formula

$$E_t\left[\mathbf{Z}_{t+k}|\mathcal{I}_t\right] = \mathbf{A}^k\mathbf{Z}_t \tag{15}$$

The vector of the discounted future paths of the variables can be calculated as

$$\sum_{k=0}^{\infty} \phi^k E_t \mathbf{Z}_{t+k} = \left(\mathbf{I} - \phi\mathbf{A}\right)^{-1} \mathbf{Z}_t \tag{16}$$

A slight modification is required to take account of the fact that changes in the growth rate of labor are dated $t+1$. Multiplying the infinite sum of future changes in the growth rate of employment by ϕ and adding $\Delta^2 l_t$ gives

$$\begin{aligned} \Delta^2 l_t + \phi \sum_{k=0}^{\infty} \phi^k \Delta^2 l_{t+k+1} &= \phi^0 \Delta^2 l_t + \phi^1 \Delta^2 l_{t+1} + \phi^2 \Delta^2 l_{t+2} + ... \\ &= e'_l \left(\mathbf{I} - \phi\mathbf{A}\right)^{-1} \mathbf{Z}_t \end{aligned} \tag{17}$$

where $\mathbf{e}_l'$ is an appropriate selection vector that singles out the present-value of employment adjustment costs. The present value of $\Delta^2 l_{t+k+1}$ is therefore given by

$$\sum_{k=0}^{\infty} \phi^k \Delta^2 l_{t+k+1} = \frac{\mathbf{e}_l' (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \Delta^2 l_t}{\phi} \tag{18}$$

We map these forecasts into the present-value representation of the Calvo pricing model to obtain an expression for the model-consistent inflation rate. This "fundamental" (Galí and Gertler 1999, p. 217) inflation rate is given by

$$\pi_t^{fund} = \gamma_s \mathbf{e}_s' (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \gamma_l \left(\mathbf{e}_l' (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \Delta^2 l_t \right) \phi^{-1} \tag{19}$$

where $\mathbf{e}_s'$ is a second selection vector that singles out the present-value of the labor share. The fundamental inflation rate is driven by the respective present-values of the labor share and employment adjustment costs.

With quadratic adjustment costs, fundamental inflation is given by

$$\pi_t^{fund} = \gamma_s \mathbf{e}_s' (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t + \gamma_l \mathbf{e}_l' \left((\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t \right)^2 \tag{20}$$

Note that the approach pursued here is similar to Bergin and Sheffrin's (2000) analysis of the present-value model of the current account. These authors include the present-value of future interest rates as an additional driving variable in an equation similar to (19).

Rudd and Whelan (2006) propose to infer the coefficients γ_s and γ_l from a regression of actual inflation on the present-value of the driving variables. We follow their suggestion and will assess the fit of the Calvo model by comparing actual inflation with fundamental inflation that results from the estimation exercise. If the model provides an accurate description of inflation, these two series must coincide.

We plot actual inflation against fundamental inflation and compute standard measures of fit. Following the literature on present-value models, Kurmann (2005) proposes two measures that indicate the extent to which the model is able to replicate actual inflation. The first measure is the ratio of standard deviations. A perfect fit would result in a standard deviation ratio of unity. In that case the Calvo model would explain all the variation in actual inflation. The second measure is the correlation coefficient between fundamental and actual inflation. Note that the two specifications, i.e. with and without employment adjustment costs, differ with respect to the number of degrees of freedom. Since our measure of fit, i.e. the correlation coefficient, corresponds to the square root of the coefficient of determination from the regression of inflation on the present values of the driving variables, we will also cross-check the results and compare a degrees of freedom-adjusted R^2 across specifications.

3.3 The role of estimation uncertainty

Note that using VAR projections disguises the degree of estimation uncertainty. To assess the accuracy of the model's fit we employ a bootstrap approach that infers the distribution of our measures of fit from estimating the model with artificial data.

We obtain confidence intervals by drawing from the residuals of the estimated model and generating new observations for the data vector using the estimated companion matrix. The VAR model is estimated again and a new coefficient matrix is computed. From this we compute the series of expected real marginal costs and regress actual inflation on the present value of future real marginal costs to infer the slope coefficient. Finally, the ratio of standard deviation and the correlation coefficient is computed. Repeating this procedure 10000 times provides us with an empirical distribution for the ratio of standard deviations and the correlation coefficient from which an interval that includes 90 percent of the estimates can be calculated.[8]

However, Kilian (1998) shows that this standard bootstrap algorithm performs poorly when it is used to compute distributions of statistics that are nonlinear functions of VAR parameters. Note that both the ratio of standard deviations and the correlation coefficient are highly nonlinear functions of the estimated VAR coefficients. Therefore, we follow Kurmann (2005) and apply Kilian's bias-corrected bootstrap algorithm. Basically, he proposes to replace the estimated VAR coefficients by bias-corrected estimates before running the bootstrap to compute the measures of fit. Details about this bias-correction can be found in Kilian (1998). The algorithm also includes a procedure for shrinking the bias estimates in case the bias-corrected VAR estimates imply that the resulting VAR becomes nonstationary. Moreover, Kilian (1998) proposes a second bias-correction because the OLS estimates are themselves biased away from their population values. Thus, the approach amounts to a bootstrap-after-bootstrap technique.

[8] By definition, this bootstrap approach respects the boundedness of the correlation coefficient. Furthermore, this approach allows for skewness and does not impose symmetry.

4 The data set

We use quarterly data for the Euro area from 1970:1 to 2003:4. All series are taken from the ECB's Area Wide Model database. The inflation rate is measured as the annualized quarterly change of the (log) GDP deflator (in percentage points). Following Coenen and Wieland (2005) and others, we account for the secular downward trend in inflation over the sample period by removing a linear time trend prior to estimation. The fitted time trend along with the inflation rate are depicted in figure (1).[9]

As explained above, real marginal costs are conventionally approximated by the labor share of income s_t (in percentage point deviation from its mean)

$$\hat{s}_t = \log \left(\frac{WL}{PY} \right)_t - mean$$

Where WL is compensation to employees, Y is real GDP and P is the price level. Employment adjustment costs are calculated as explained above using the total employment variable due to the lack of an appropriate series of hours worked for the Euro area.

5 Results

The GMM estimates of the reduced and structural form coefficients are reported in table (1). Note that, in the reduced form estimation, costs of adjusting the labor input are highly significant for explaining inflation. The estimated coefficient is 0.077, which is double that of the impact of the labor share on inflation. Interestingly, the labor share enters significantly only if we also include employment adjustment costs. Quadratic adjustment costs, on the contrary, enter insignificantly.

Estimates from the structural form support this finding. Most importantly for our purpose, the estimates assign a significant role to employment adjustment costs with estimates of δ being significantly different from zero. Note that the degree of price stickiness is reflected in the estimates of the Calvo adjustment probability μ, which in turn determines the average duration of Calvo contracts D. The duration of sticky price contracts is found to lie between 5 and 8 quarters. These estimates are perfectly in line with existing macro evidence. Nevertheless, micro evidence collected under

[9]The results are robust with respect to detrending.

the auspices of the ECB's Inflation Persistence Network point to a somewhat shorter duration of contracts, see Dhyne et al. (2004).

Given that GMM estimates lend support to the role of labor adjustment costs, we proceed by estimating the forecasting VAR model with three lags ($q = 3$) and calculating fundamental inflation according to the model laid out before. To check for robustness, we will also report results for a VAR system with five lags. Following Rudd and Whelan (2006), actual inflation is regressed on a constant and the present-value of future real marginal costs in order to infer the parameters γ_s and γ_l. We then compare the series of fundamental inflation with actual inflation by means of the ratio of their standard deviations, their correlation coefficient, and a degree-of-freedom adjusted measure of fit. The discount factor is set to $\phi = 0.99$, which is the reference parameterization in the literature.

Figure (2) depicts the time series of actual and model-consistent or fundamental inflation rates that take account of employment adjustment costs. We find that the augmented Calvo model tracks the behavior of the actual inflation rate remarkably well. Figure (3), on the other hand, depicts these two time series without taking account of employment adjustment costs, i.e. with $\gamma_l \equiv 0$. The difference is striking. Apparently, the model that neglects costly labor adjustment can hardly explain inflation dynamics. Table (2) reports the main estimates of our measures of fit together with the bootstrapped confidence bands.

In the baseline model, the ratio of standard deviations of fundamental and actual inflation is 0.63 and the correlation between both series is 0.60. These numbers confirm the visual impression from the beforementioned figures and seem to indicate a reasonable fit of the New Keynesian Phillips Curve. Neglecting the role of employment adjustment costs results in a substantially poorer fit with a standard deviations ratio of 0.41 and a correlation between actual and fundamental inflation of 0.39. Accounting for employment adjustment costs, thus, greatly improves the explanatory power of the basic New Keynesian model. Note that the point estimates of the measures of fit that take account of costly employment adjustment lie outside (i.e. above) the confidence band of the measures of fit that disregard employment adjustment costs, e.g. $corr = 0.60 \notin [0.26, 0.41]$. Figure (4) presents the distributions of the measures of fit across bootstrap replications for the model with and without employment adjustment costs. Visual inspection confirms the finding that the augmented model is superior.

Figure (5) plots the autocorrelation functions of actual inflation and fundamental inflation under both scenarios, i.e. with and without employment adjustment costs. While the specification with costly labor adjustment replicates the dependence of inflation on its own lags quite accurately, the model with frictionless labor markets severely overstates the persistence of inflation. Overall, the results point to a significant role of imperfect labor markets in explaining aggregate inflation dynamics.

The correlation coefficient between actual and fundamental inflation corresponds to the square root of the R^2 of the auxiliary regression that relates inflation to the two present values of the driving variables. Therefore, we can check whether the loss of one degree of freedom in the adjustment costs specification affects the results. For that purpose, we compare the square roots of the degrees of freedom-adjusted R^2 across specifications. This measure corresponds to the correlation between actual and fundamental inflation with a penalty for loosing one degree of freedom if employment adjustment costs are included. It turns out that the adjustment costs remain a significant determinant of inflation dynamics.

To check the robustness of these results, we modify the lag order of the underlying VAR model. Table (3) also reports results based on a VAR system with five lags ($q = 5$). The results corroborate the beformentioned findings and confirms their robustness. Removing a linear time trend in addition to removing the mean from the labor share of income (these results are not reported) does also not alter the main findings. Hence, if we allow for a richer measure of marginal costs and take employment adjustment costs into account, we obtain a well fitting model for inflation dynamics.

The alternative measure of adjustment costs, i.e. the squared growth rate of employment, enters significantly in the VAR model with three lags whose results are presented in table (4). All three measures of fit underline the economic role of labor market frictions for explaining actual inflation. Only the VAR model with five lags and quadratic adjustment costs, see table (5), cannot support a significant role of factor adjustment costs.

6 Conclusions

Under the New Keynesian paradigm, forward-looking inflation dynamics are driven by the present value of marginal costs. Previous studies approximate marginal costs by deviations of the labor share of income from its mean. This papers shows that a more realistic specification of marginal costs that takes account of labor market imperfections results in a much better empirical fit. Estimates of structural Phillips curve parameters support the significant role of employment adjustment costs. Furthermore, supplementing the forward-looking model with a measure of employment adjustment costs generates a series of fundamental inflation that matches the behavior of aggregate Euro area inflation surprisingly well. Hence, this paper shows that departing from restrictive assumptions and allowing for a richer supply side in forward-looking models of inflation dynamics provides a more accurate replication of actual inflation.

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Table 1: Results from reduced and structural form GMM estimates

reduced form	Parameters				Test
	ϕ	γ_s	γ_l		J
with $(\Delta l_t - \Delta l_{t+1})$	0.886 (0.085)	0.034 (0.015)	0.077 (0.018)		0.116
with $(\Delta l_t)^2$	0.928 (0.058)	0.012 (0.010)	0.002 (0.004)		0.121
without adjustment costs	0.944 (0.065)	0.019 (0.012)			0.103
structural form	Parameters			Duration	Test
with $(\Delta l_t - \Delta l_{t+1})$	ϕ	μ	δ	D	J
I	0.965 (0.097)	0.805 (0.034)	1.631 (0.521)	5.13	0.116
II	0.886 (0.085)	0.869 (0.032)	2.230 (0.925)	7.63	0.116

Notes: Newey-West corrected standard errors in parenthesis. The two alternative orthogonality conditions are denoted by I and II. D denotes the average duration of sticky-price Calvo contracts (in quarters) which is given by $(1-\mu)^{-1}$. The last column reports p-values from J-Tests of the validity of overidentifying restrictions. The set of instruments includes five lags of π_t, $\hat{s}_t$, the measure of adjustment costs, and the output gap (obtained from Hodrick-Prescott filtering) and two lags of the short-term interest rate. The sample spans 1970:1 - 2003:4.

Table 2: The uncertain fit of the NKPC and the role of employment adjustment costs based on a VAR(3)

model	measure of fit	estimate	90% conf. band
with PV of $\Delta^2 l_t$	std.dev. ratio	0.63	$\left[\ 0.40 \quad 0.76\ \right]$
	corr.	0.60	$\left[\ 0.38 \quad 0.72\ \right]$
	$\sqrt{R^2_{dof-adj.}}$	0.63	$\left[\ 0.38 \quad 0.75\ \right]$
without PV of $\Delta^2 l_t$	std.dev. ratio	0.41	$\left[\ 0.28 \quad 0.43\ \right]$
	corr.	0.39	$\left[\ 0.26 \quad 0.41\ \right]$
	$\sqrt{R^2_{dof-adj.}}$	0.41	$\left[\ 0.26 \quad 0.42\ \right]$

Notes: The forecasting VAR with $q = 3$ lag contains $\left[\hat{s}_t, \pi_t, \Delta^2 l_t\right]'$, where π_t is linearly detrended and $\Delta^2 l_t$ is the second difference of employment. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications. PV stands for the present-value of the forcing variable. The ratio of standard deviations is $\frac{std.dev.\left(\pi^{fund}\right)}{std.dev.\left(\pi^{actual}\right)}$ and the correlation is $corr\left(\pi^{fund}, \pi^{actual}\right)$. The degrees-of-freedom adjusted measure of fit is denoted by $\sqrt{R^2_{dof-adj.}}$.

Table 3: The uncertain fit of the NKPC and the role of employment adjustment costs based on a VAR(5)

model	measure of fit	estimate	90% conf. band
with PV of $\Delta^2 l_t$	std.dev. ratio	0.53	$\begin{bmatrix} 0.23 & 0.70 \end{bmatrix}$
	corr.	0.58	$\begin{bmatrix} 0.25 & 0.76 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.57	$\begin{bmatrix} 0.23 & 0.75 \end{bmatrix}$
without PV of $\Delta^2 l_t$	std.dev. ratio	0.34	$\begin{bmatrix} 0.15 & 0.48 \end{bmatrix}$
	corr.	0.37	$\begin{bmatrix} 0.17 & 0.53 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.36	$\begin{bmatrix} 0.16 & 0.52 \end{bmatrix}$

Notes: The forecasting VAR with $q = 5$ lags contains $\left[\hat{s}_t, \pi_t, \Delta^2 l_t\right]'$, where π_t is linearly detrended and $\Delta^2 l_t$ is the second difference of employment. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications. PV stands for the present-value of the forcing variable. The ratio of standard deviations is $\frac{std.dev.\left(\pi^{fund}\right)}{std.dev.\left(\pi^{actual}\right)}$ and the correlation is $corr\left(\pi^{fund}, \pi^{actual}\right)$. The degrees-of-freedom adjusted measure of fit is denoted by $\sqrt{R^2_{dof-adj.}}$.

Table 4: The uncertain fit of the NKPC and the role of quadratic employment adjustment costs based on a VAR(3)

model	measure of fit	estimate	90% conf. band
with PV of $(\Delta l_t)^2$	std.dev. ratio	0.44	$\begin{bmatrix} 0.32 & 0.67 \end{bmatrix}$
	corr.	0.45	$\begin{bmatrix} 0.32 & 0.68 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.43	$\begin{bmatrix} 0.30 & 0.67 \end{bmatrix}$
without PV of $(\Delta l_t)^2$	std.dev. ratio	0.39	$\begin{bmatrix} 0.26 & 0.41 \end{bmatrix}$
	corr.	0.41	$\begin{bmatrix} 0.28 & 0.43 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.41	$\begin{bmatrix} 0.26 & 0.42 \end{bmatrix}$

Notes: The forecasting VAR with $q = 5$ lags contains $\left[\hat{s}_t, \pi_t, \Delta^2 l_t\right]'$, where π_t is linearly detrended and $(\Delta l_t)^2$ is the growth rate of (log) employment. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications. PV stands for the present-value of the forcing variable. The ratio of standard deviations is $\frac{std.dev.\left(\pi^{fund}\right)}{std.dev.\left(\pi^{actual}\right)}$ and the correlation is $corr\left(\pi^{fund}, \pi^{actual}\right)$. The degrees-of-freedom adjusted measure of fit is denoted by $\sqrt{R^2_{dof-adj.}}$.

Table 5: The uncertain fit of the NKPC and the role of quadratic employment adjustment costs based on a VAR(5)

model	measure of fit	estimate	90% conf. band
with PV of $(\Delta l_t)^2$	std.dev. ratio	0.43	$\begin{bmatrix} 0.24 & 0.68 \end{bmatrix}$
	corr.	0.45	$\begin{bmatrix} 0.25 & 0.72 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.44	$\begin{bmatrix} 0.23 & 0.71 \end{bmatrix}$
without PV of $(\Delta l_t)^2$	std.dev. ratio	0.34	$\begin{bmatrix} 0.15 & 0.48 \end{bmatrix}$
	corr.	0.37	$\begin{bmatrix} 0.17 & 0.53 \end{bmatrix}$
	$\sqrt{R^2_{dof-adj.}}$	0.30	$\begin{bmatrix} 0.16 & 0.52 \end{bmatrix}$

Notes: The forecasting VAR with $q = 5$ lags contains $\left[\hat{s}_t, \pi_t, \Delta^2 l_t\right]'$, where π_t is linearly detrended and $(\Delta l_t)^2$ is the growth rate of (log) employment. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications. PV stands for the present-value of the forcing variable. The ratio of standard deviations is $\frac{std.dev.\left(\pi^{fund}\right)}{std.dev.\left(\pi^{actual}\right)}$ and the correlation is $corr\left(\pi^{fund}, \pi^{actual}\right)$. The degrees-of-freedom adjusted measure of fit is denoted by $\sqrt{R^2_{dof-adj.}}$.

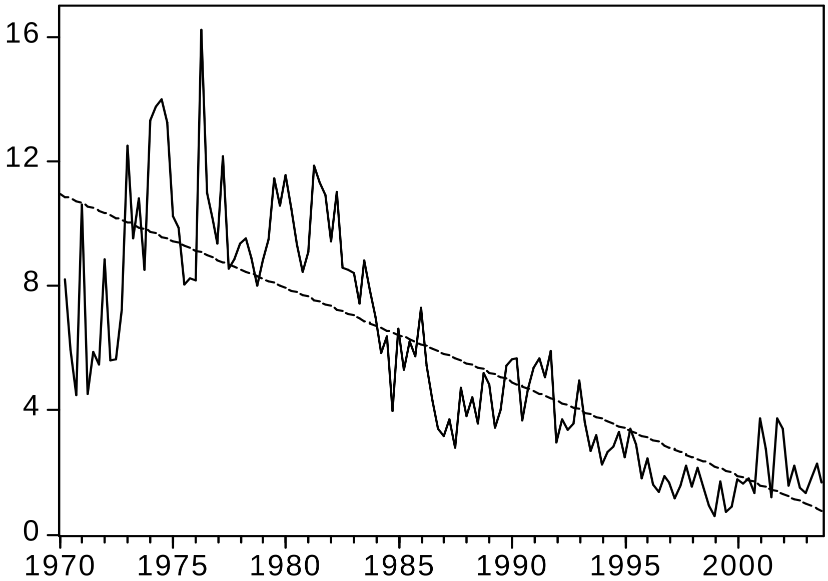

Figure 1: Actual (bold line) inflation rate in the Euro area (in % p.a.) and fitted time trend (dotted line)

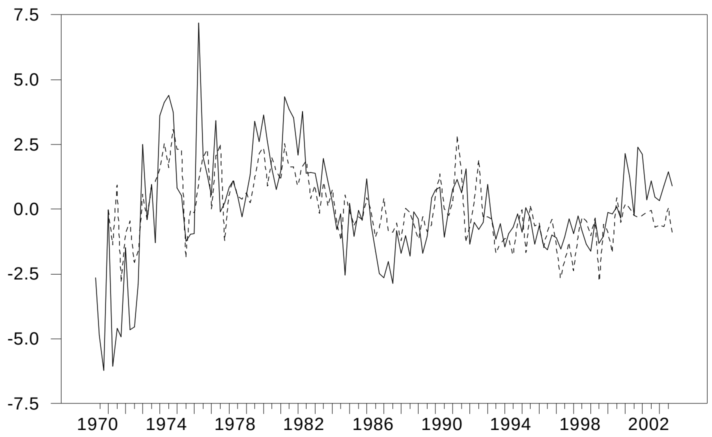

Figure 2: Actual (bold line) and fundamental (dotted line) inflation rate (detrended) in the Euro area (in % p.a.) with employment adjustment costs

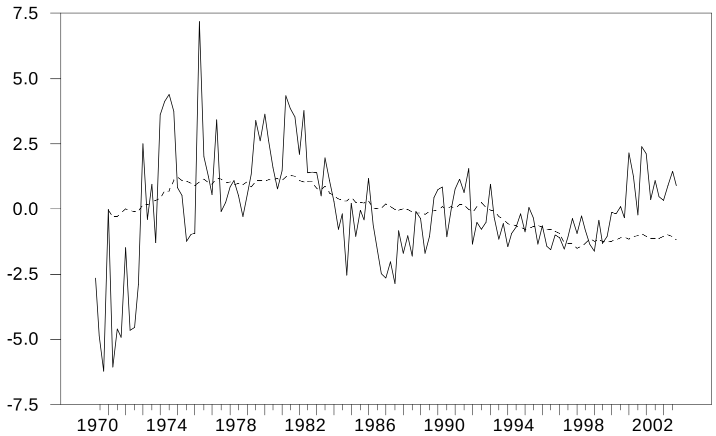

Figure 3: Actual (bold line) and fundamental (dotted line) inflation rate (detrended) in the Euro area (in % p.a.) without employment adjustment costs

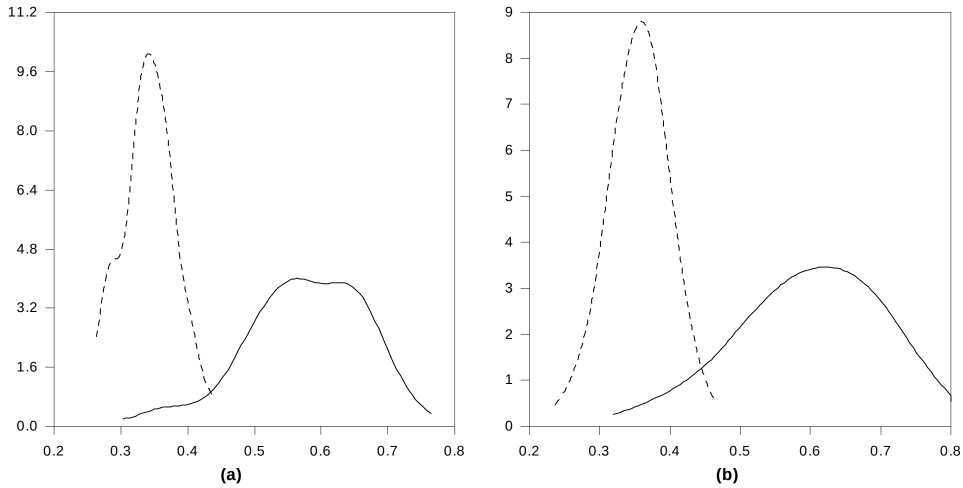

Figure 4: Distribution of (a) ratio of standard deviations and (b) correlation coefficient across bias-corrected bootstrap replications for model with (solid line) and without (dotted line) employment adjustment costs

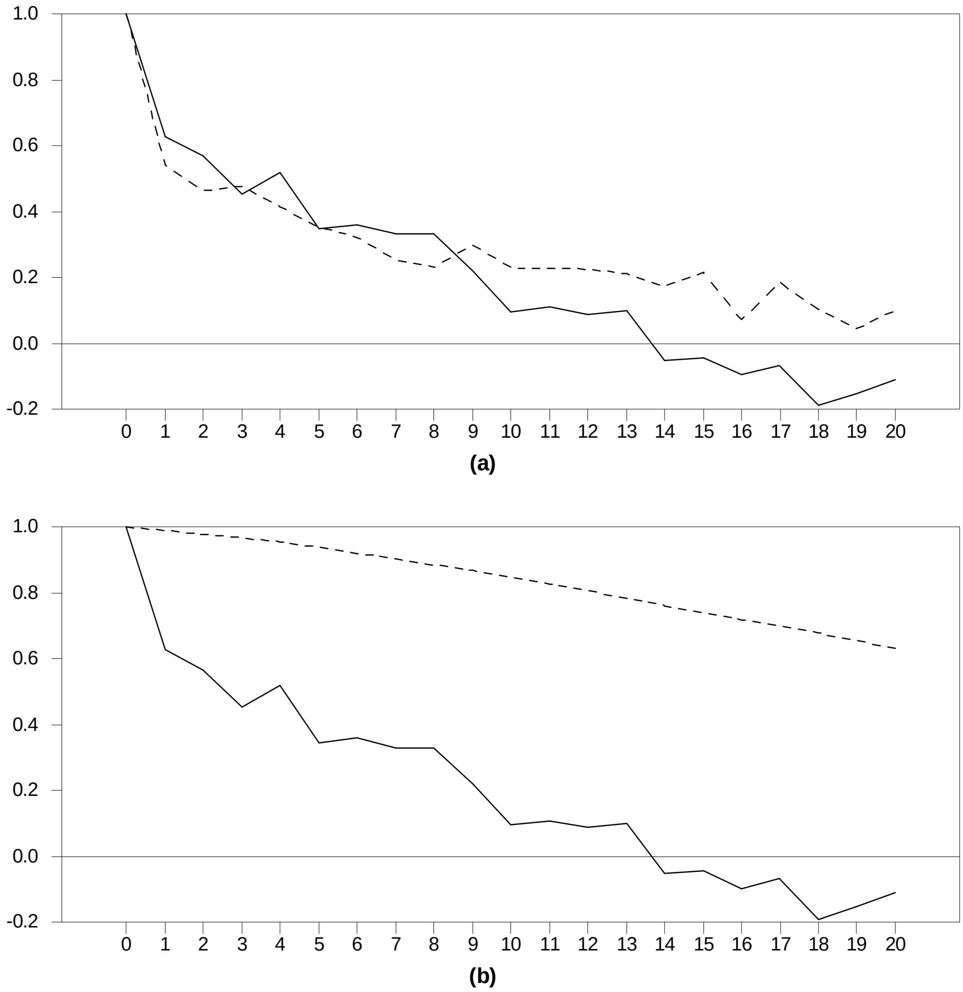

Figure 5: Autocorrelation functions of inflation (solid line) and fundamental inflation (dotted line) with (a) labor adjustment costs and without (b) labor adjustment costs